Geant4 10.4, 10.5 and 10.6

Selected highlights

Based on talks by G. Cosmo, V. Ivanchenko, A. Ribon, A. Howard, E. Mendoza Cembranos and others

Krzysztof Genser/Fermilab/SCD

Physics and Detector Simulation (PDS) Group Leader
LArSoft Coordination Meeting
April 7th, 2020

Outline

- Excerpts from Geant4 Technical Fora held on
  - January 17th, April 10th, 2018 on Geant4 10.4 and patch
  - January 19th, 2019 on Geant4 10.5
  - January 16th, March 23rd, 2020 on Geant4 10.6 and patch Paraphrased and augmented by myself, with a focus on Fermilab neutrino experiments, using various sources including the release notes
    - See the fora pages mentioned in the talk for the original slides and links to the release notes and other sources for more information
    - See Geant4 Bugzilla site to learn about problem reports
      - e.g.: https://bugzilla-geant4.kek.jp/show_bug.cgi?id=2087
- Some CPU cost related info
- Summary/Suggestions

Geant4 10.4; released December 8th, 2017

- Technical forum: https://indico.cern.ch/event/680975/timetable/#20180117.detailed

16:00		
General introduction of version 10.4 and prospect	*Makoto Asai*	
13-2-005, CERN	16:00 - 16:12	
Highlights of version 10.4 - non–physics part	*Gabriele Cosmo*	
13-2-005, CERN	16:12 - 16:24	
Highlights of version 10.4 – EM physics	*Prof. Vladimir Ivantchenko*	
13-2-005, CERN	16:24 - 16:36	
Highlights of version 10.4 – Hadronic physics	*Alberto Ribon*	
13-2-005, CERN	16:36 - 16:48	
Open requirements	*Marc Verderi*	
13-2-005, CERN	16:48 - 17:00	
17:00		
ALICE Report	*Ivana Hrivnacova*	
13-2-005, CERN	17:00 - 17:15	
Validation of VecGeom for CMS simulation	*Sunanda Banerjee*	
13-2-005, CERN	17:15 - 17:30	
Status and plans for CMS simulation	*Vladimir Ivantchenko*	
13-2-005, CERN	17:30 - 17:45	
ATLAS Report	*John Derek Chapman*	
13-2-005, CERN	17:45 - 18:00	
18:00		
CCFE Contributions to Geant4/V	*Dr. Andrew Davis*	
13-2-005, CERN	18:00 - 18:15	

- Release notes:
  - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/Patch4.10.4-1.txt - 2/28, 2018
  - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/Patch4.10.4-2.txt - 5/28, 2018
  - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/Patch4.10.4-3.txt - 2/8, 2019

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Selected information from non-physics highlights

- Geometry/Geometrical primitives
  - **Updated VecGeom** library
    - Optional replacement of original Geant4 solids
      - Selection made at configuration
    - External library VecGeom
      - https://gitlab.cern.ch/VecGeom/...
    - **Deprecated & replaced old USolids interfaces and wrapping system**
    - Shapes Available for replacement:

      Box, Trapezoid (Trap), Simple Trapezoid (Trd), Orb, Sphere (+ sphere section), Tube (+ cylindrical section) , Cone (+ conical section), Generic Trapezoid (Arb8), Polycone (PCon), Polyhedron (PGon), Parallelepiped (Para), Paraboloid, Torus (+ torus section)

  - **Added new construct, G4MultiUnion as native type,**
    - **implementing a multiple-union of several volumes, displaced/rotated and same material**

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Selected information from non-physics highlights (cont'd)

- Geometry/Volumes, Field transport
  - **New revised algorithms for basic shapes (box, trap, trd, para,...)**
    - **Providing more compact implementation and CPU speedup**
  - Implemented specialized constructs for trap and extruded-solid
    - Trd-like structure and convex/non-convex right prism
  - Fixed static memory leaks from geometry objects in MT mode
  - **New stepper**, G4DormandPrince745, now set as the default stepper for magnetic fields, providing higher accuracy than G4ClassicalRK4, the old default
    - **It requires fewer field evaluations for similar accuracy**
    - (Many experiments set their own default stepper)

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Selected information from non-physics highlights (cont'd)

- Persistency
  - New GDML schema v3.1.6
  - **Added possibility to specify material properties tables for optical surfaces**
  - Added ability to export limited number of levels in geometry hierarchy
  - Added UI commands to enable/disable stripping of names for reading and for appending or not pointers to names for writing
  - Enabled import/export of G4MultiUnion as a native type
- Particles
  - **Updated properties according to PDG-2017**
  - Introduced G4MuonicAtoms (not used in any physics list yet)

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Selected information from non-physics highlights (cont'd)

- ## Global
  - New structure for G4coutDestination functionality with division between sink and filter

- ## Run
  - **Modified design of physics-lists for allowing cleanup of memory in MT mode**
    - New class G4PhysicsBuilderInterface which all physics-lists builders inherit from
  - Prevented adding the same sensitive detector to the same logical volume multiple times

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Selected information from non-physics highlights (cont'd)

- Data sets
  - New versions of the data files
    - G4EMLOW-7.3 - low energy electromagnetic processes
    - G4ENSDFSTATE-2.2 - nuclides properties
    - G4RadioactiveDecay-5.2 - radioactive decay hadronic processes
    - G4PhotonEvaporation-5.2
    - G4ABLA-3.1 - nuclear shell effects in INCL/ABLA hadronic mode
    - G4RealSurface-2.1 - measured optical surface reflectance
    - G4TENDL-1.3.2 - (optional) incident particle nuclear data library
  - **https://geant4.web.cern.ch/support/data_files_citations**
- **CLHEP**
  - **New version 2.4.0.0**
    - **With MixMax random engine as the default engine, replacing HepJamesRandom (https://en.wikipedia.org/wiki/MIXMAX_generator)**
      - **ART defines HepJamesRandom as the default as of ART 3.02.04**
        - **(which as of ART 3.04 can be overwritten and MixMax selected)**

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Selected information from EM physics highlights

- Materials for EM and Optical physics
  - New interfaces to the density effect parameterizations:
    - User may add custom density effect parameterization per material
      - G4Material::GetIonisation()->SetDensityEffectParameters(G4double cd, G4double md, G4double ad, G4double x0, G4double x1, G4double x2);
  - User may scale density effect parameterization from base material
    - G4Material::GetIonisation()->SetDensityEffectParameters(const G4Material* base_mat);
- Material property table
  - Added new interfaces to G4MaterialPropertyTable
    - **Used enumerator instead of a string as a key for a property lookup during run time (used in Scintillation, Cerenkov and several Optical Photon processes) which resulted in significant CPU savings**
    - Kept old interfaces for backward compatibility
    - Made this table thread safe
- Added M. Stockhoff et al.'s DAVIS Model for optical simulations
  - reflectance model based on measured data LUT (Look-Up-Tables)

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Selected information from EM physics highlights (cont'd)

- EM infrastructure updates
  - Added a new interface to G4VEmModel allowing enabling triplet production
    - Useful for gamma conversion, bremsstrahlung, positron annihilation
    - Different model is used for sampling of final states when a primary particle interacts with atomic electron
- Fixed mechanism of model enumeration for EM physics
  - Users may identify production model for gamma and electrons
- **EM web documentation reviewed and updated**
  - See e.g. http://geant4.web.cern.ch/collaboration/working_groups/electromagnetic
- EM testing suite significantly updated
- New example for dark matter particles simulation

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Selected information from EM physics highlights (cont'd)

- Updates to the standard models
  - **Updated models of fluctuation of energy loss**
    - Urban model of fluctuations and the PhotoAbsorption Ionization (PAI) model
    - Fix in low-energy hadron transport
    - Fix in nuclear stopping
    - Low limit for cut in PAI model is set to 12.5 eV
      - Needed for gaseous detector simulations
  - Models of single and multiple scattering for e-/e+
    - Added Mott corrections to Goudsmit-Saunderson (GS) model and to the single scattering
      - Providing "errorless" mechanism of tracking near geometry boundary
      - **new model improves significantly the e–/e+ transport accuracy: (at least) competitive with standard simulation toolkits like**
        - EGSnrc (National Research Council Canada Electron Gamma Shower)
        - PENELOPE (PENetration and Energy LOss of Positrons and Electrons)
      - https://indico.cern.ch/event/647154/contributions/2718743/attachments/1529680/2393555/MNovak_geant4_22.pdf
    - Updated relativistic scattering model
  - Gamma models
    - Fixed inconsistency in LPM (Landau–Pomeranchuk–Migdal) correction computation
    - Improved sampling of e- angles in photo-effect

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# Selected information from EM physics highlights (cont'd)

- ## Low Energy EM Physics

  - Livermore photo-electric model

    - EPICS2014 (Electron and Photon Interaction Cross Sections) data used for shell cross sections
    - Improved parameterizations of cross sections

  - Atomic de-excitation

    - Updated set of shell ionization cross sections for protons based on calculations by M. Reis et al.

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Selected information from EM physics highlights (cont'd)

- EM Physics Lists configurations
  - Several EM physics constructors (Physics List components) are provided, main modifications are in
    - G4EmStandardPhysics – default
      - Includes Livermore photo-electric model and Rayleigh scattering
      - No CPU performance degradation expected due to code optimizations
    - G4EmStandardPhysics_option4 (**_EMZ** suffix) – a combination of the most accurate EM models
      - Includes the GS model with Mott corrections and "errorless" stepping
    - G4EmStandardPhysicsGS – alternative multiple scattering
    - G4EmStandardPhysicsSS – single scattering
      - very CPU demanding

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Selected information from EM physics highlights (cont'd)

Backscattering validation results
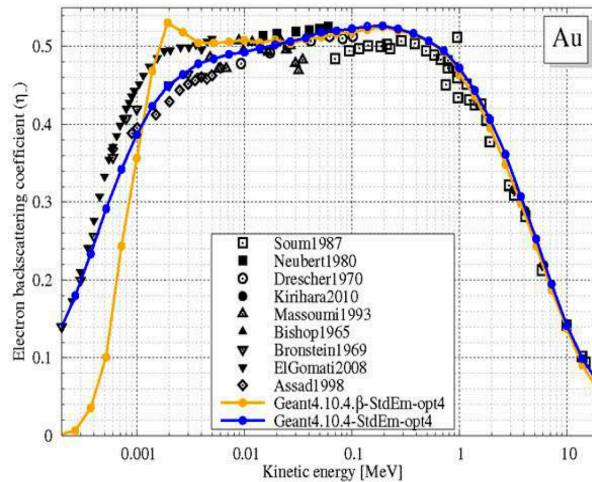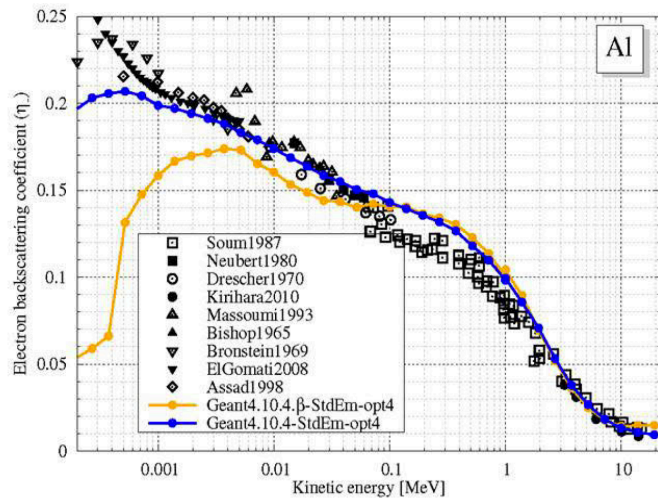
- Simulation of electron backscattering from Al (left) and Au (right) targets versus data from different experiments.
- Opt4 EM configuration is with the Urban model (yellow) and the GS model with "error-free" stepping (blue)

7 Geant4 EM physics   17/01/2018

Blue line shows the EM Opt4 (_EMZ) results

Selected information from hadronic physics highlights

- String models
  - FTF (Fritiof)
  - produces hadronic showers similar to those of Geant4 10.3 (which were similar to those in 10.1)
    - **Introduced smearing of resonance masses**
    - **Improved antibaryon annihilations**
  - QGS (Quark Gluon String) stays the same as in Geant4 10.3
- Intra-nuclear Cascade models
  - Bertini-like (BERT)
    - A few fixes
  - Liege (INCLXX)
    - **Extended to include strangeness**
      - Treatment of primary kaons and hyperons, and production of secondary kaons and hyperons
    - Improved simulation of few nucleon removal

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Selected information from hadronic physics highlights (cont'd)

- Precompound / de-excitation models
  - Several code improvements
  - New data-set: PhotonEvaporation5.2

- Production and transport of long-lived isomers is enabled in hadronic models which use native de-excitation module (e.g. not in Bertini if used with its own Precompund/de-excitation)
  - Only isomers with a half-life above a time threshold are created: by default it is set to 1000 seconds, **unless radioactive decay is enabled (like in the Shielding physics lists) in which case this threshold is 1 microsecond**

Selected information from hadronic physics highlights (cont'd)

- Radioactive Decay model
  - Several improvements and fixes, including in biasing
  - Correlated gamma emission in radioactive decay is implemented but disabled by default
  - New data-set: RadioactiveDecay5.2
  - **When radioactive decay is activated, Atomic de-excitation (fluorescence and Auger emission) is switched on (overriding any EM default settings), Internal Conversion is switched on**
- Added an alternative implementation of muon stopping using muonic atoms
  - https://indico.cern.ch/event/647154/contributions/2714249/attachments/1528955/2392057/MuAtomsG420170920.pdf
  - Disabled by default

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Geant4 patches 10.4.p01, 10.4.p02, 10.4.p03

- Technical forum: https://indico.cern.ch/event/713118/timetable/#20180410.detailed

General introduction and prospect	*Makoto Asai*
32-1-A24, CERN	16:00 - 16:12
Summary of recent patch release & 2018 work plan - non–physics part	*Gabriele Cosmo*
32-1-A24, CERN	16:12 - 16:24
Summary of recent patch release & 2018 work plan - EM physics part	*Prof. Vladimir Ivantchenko*
32-1-A24, CERN	16:24 - 16:36
Summary of recent patch release & 2018 work plan - Hadronic physics part	*Alberto Ribon*
32-1-A24, CERN	16:36 - 16:48
Status of open requirements	*Marc Verderi*
32-1-A24, CERN	16:48 - 17:00
ATLAS Report	*John Derek Chapman*
32-1-A24, CERN	17:00 - 17:20
New CMS Requirements	*Sunanda Banerjee*
32-1-A24, CERN	17:20 - 17:40

- Release notes:
    - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/ReleaseNotes4.10.4.html - 12/8, 2017
    - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/Patch4.10.4-1.txt - 2/28, 2018
    - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/Patch4.10.4-2.txt - 5/28, 2018
    - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/Patch4.10.4-3.txt - 2/8, 2019
    - Patch releases address known deficiencies of a specific release; are not meant for introduction of new functionalities

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Selected 10.4.p01 fixes

- Configuration:
  - CMake:
    - Added c++17 to C++ standards against which Geant4 can be compiled, as experimental build. Will require a minimum CMake version 3.8 to enable, but this is not checked.

- Geometry:
  - navigation:
    - **Fix for momentum value** in G4PathFinder::SetChargeMomentumMass(); where magnitude square was passed instead of magnitude. Addressing problem report #2037 (**affecting tracking with spin, use by e.g. Muon g-2**).
  - solids/CSG (Constructive Solid Geometry)
    - Fixed typo in G4Trd::GetPointOnSurface() for the area settings
    - Correction in G4UPara wrapper in ComputeDimensions() to add explicit cast for the solid type to parameterize.
    - solids/specific:
      - **Added missing initialization of two data-members in copy-ctor and assignment operator of G4ExtrudedSolid**. Addressing problem report #2016.
      - Removed redundant data initialization in G4ExtrudedSolid constructors.

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Selected 10.4.p01 fixes (cont'd)

- Materials:
  - **Re-enable user-defined material properties in G4MaterialPropertiesTable** and G4MaterialPropertiesIndex. Addressing problem report #2030.
  - Fixed self-consistency in headers (missing #include) in G4ElementTable and G4MaterialTable.
- Processes - Electromagnetic:
  - standard:
    - G4PairProductionRelModel: fixed misuse of G4Pow (A13(..) should be used instead of Z13(..)); added initialization of an element cache before sampling of final state. Partially addressing problem report #2017.
  - utils:
    - G4EmParameters, G4VEmProcess, G4VEnergyLossProcess: define the same default values for few internal members.
    - G4EmParameters, G4EmParametersMessenger: fixed printout format and added lock and protection in commands defining physics per region.

Selected 10.4.p02 fixes

- Navigation:
  - G4Navigator::GetLocalExitNormal(): fix for normal calculated at the endpoint of current step, on a 'candidate' next volume. Adds missing transformation to the frame of the current volume. Addresses problem report #2054
- Solids/CSG:
  - G4Box: simplified and optimized calculation of normal in method DistanceToOut(p,v,..).
- Particles:
  - **G4PhaseSpaceDecayChannel**: fixed incorrect indexing in ManyBodyDecayIt(), **causing incorrect setting of daughter momentum in 4-body phase-space decay**. Addressing problem report #2053
- **Patched data set for measured optical surface reflectance** G4RealSurface-2.1.1:
  - Merged LBNL lookup tables (LUTs) data introduced in 2.0 with the Davis LUTs. Addressing problem report #2043.

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Selected 10.4.p03 fixes
(mostly quoted from the releases notes)

- Global:
  - G4PhysicsVector, G4Physics2DVector: fixed possible out-of-bound access in FindBin() method. Addressing problem report #2087.

- Processes - Electromagnetic:
  - **G4Cerenkov, G4Scintillation: correctly reset number of optical photons to 0 in each step**. Addressing problem report #2056. **Added protection against infinite loops due to very small steps**. Addressing problem report #1992.

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Selected 10.4.p03 fixes, cont'd

- Processes - Hadronic:

  - management:

    - G4HadronicProcess: added a check if secondary particle is on the mass shell; **if its mass differ from the PDG mass more for 1.5 MeV then mass is forced to the mass shell, energy conserved, but momentum is changed**. **Use correct return type** when calling CheckResult() from PostStepDoIt() fixes case when the value of pointer 'result' does not get properly reset to NULL in case a non-conservation is detected, thus "bad" interaction does not get re-sampled.

  - models/cascade:

    - **G4GDecay3**: (three-body phase space momentum generator) fixed problem reported by CMS due to wrong kinematics in the final state by removing loop check; adding protection for low value of mother mass.

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Selected 10.4.p03 fixes, cont'd

- Processes - Hadronic:
  - models/parton_string/diffraction
    - G4FTFAnnihilation: **fix to get flat cos(theta) and phi distributions for antiproton annihilation at rest**.
  - **models/particle_hp**
    - G4ParticleHPCaptureFS::ApplyYourself(): **Lorentz boost of neutron into target frame was backwards; reversed it**. Also replaced SetDefinition() with SetDefinitionAndUpdateE(). Addresses problem report #1919.
    - Fixed definition of singletons for G4ParticleHPManager and G4ParticleHPThreadLocalManager and some code cleanup.
    - Made **G4ParticleHPThreadLocalManager** a G4ThreadlLocalSingleton to **avoid memory leaks generated each time a thread creates the instance**.

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Selected 10.4.p03 fixes, cont'd

- Processes - Hadronic:

  - **models/particle_hp**

    - Fixed incorrect sampling of isotropic distribution. Addressing problem report #1745.

    - Fixed gamma level mismatch in G4ParticleHPInelasticCompFS. Not a complete fix because gamma data comes from ENSDF (Evaluated Nuclear Structure Data File) and does not necessarily match excitations in ENDF (Evaluated Nuclear Data File). Addressing problem report #1789.

    - Fixed memory leaks in G4ParticleHPContEnergyAngular::Sample() and G4ParticleHPContAngularPar::cacheInit(). Addressing problem report #2026.

    - G4ParticleHPElasticFS::ApplyYourself(): **use correct reference frames for calculation of projectile and target momenta**. Correction made for cases when cos(Theta) is given in lab frame and in center of momentum frame. Partial fix of momentum non-conservation for problem report #1918

    - Fixed potential memory leaks in G4ParticleHPPhotonDist, G4ParticleHPContAngularPar and G4ParticleHPFinalState while using pointers cached in G4Cache.

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Geant4 10.5; released December 7th, 2018

- Technical forum: https://indico.cern.ch/event/780834/timetable/#20190118.detailed

16:00	General introduction and prospect	Makoto Asai
	13/2-005, CERN	16:00 - 16:05
	Highlights of version 10.5 - non-physics part	Dr Gabriele Cosmo
	13/2-005, CERN	16:05 - 16:15
	Highlights of version 10.5 - EM physics part	Prof. Vladimir Ivantchenko
	13/2-005, CERN	16:15 - 16:25
	Highlights of version 10.5 - Hadronic physics part	Alberto Ribon
	13/2-005, CERN	16:25 - 16:35
	Birk's Quenching	Alberto Ribon
	13/2-005, CERN	16:35 - 16:45
	Open requirements	Marc Verderi
	13/2-005, CERN	16:45 - 16:55
17:00	ALICE	Ivana Hrivnacova
	13/2-005, CERN	17:00 - 17:15
	ATLAS	Marilena Bandieramonte
	13/2-005, CERN	17:15 - 17:30
	CMS	Vladimir Ivantchenko
	13/2-005, CERN	17:30 - 17:45
	Modeling dust clouds in Geant4	Dr Ara Knaian
	13/2-005, CERN	17:45 - 18:00
18:00		

- Release notes:
  - http://geant4.web.cern.ch/geant4/support/ReleaseNotes4.10.5.html
  - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/Patch4.10.5-1.txt - 4/17 2019

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Selected information from non-physics highlights

- ## Geometry - Geometrical primitives
  - Updated **VecGeom** library, VecGeom v01.01.00
    - Selection which shapes to enable made at the configuration stage
    - Removed old USolids module and interfaces; cleaned up setup
    - Revision of most shapes with update of internal API
    - New tessellated section helper used in complex faceted solids
    - Addition of **Multi-union** and Tetrahedron
    - Available shapes for replacement:
      - Box, Trapezoid (Trap), Simple Trapezoid (Trd), Parallelepiped (Para), Orb, Sphere (+ sphere section), Tube (+ cylindrical section) , Cut Tube, Cone (+ conical section), Generic Trapezoid (Arb8), Polycone (PCon), Polyhedron (PGon), Parallelepiped (Para), Paraboloid, Hyperboloid, Torus (+ torus section), Tetrahedron (Tet), Tessellated Solid, Extruded Solid
  - **Reimplemented EstimateSurfaceArea() for approximate calculation of the surface area of a solid**
    - New more performant algorithm, providing more accurate estimation

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Selected information from non-physics highlights (cont'd)

- Geometry - Transportation, Field
  - **Treatment of looping particles in transportation has been reviewed:**
    - **Only stable particles are killed if they 'loop',** i.e. take more than the maximum (default 1000) integration steps in one physics step; unstable particles are now propagated indefinitely
      - 100 MeV (warning energy): below this, tracks are killed silently
      - 250 MeV (important energy): above this, tracks are given multiple chances (10 physics steps)
    - Settings are fully under user control
      - New methods in G4PhysicsListHelper allow the user to select a set of low/high values of 'looper' energy thresholds
    - Enhanced diagnostics for looping particles
    - Addressing problem report # 2063
  - Correction in G4MagneticField to no longer inherit from G4ElectroMagneticField
  - Introduced Bulirsch-Stoer integration algorithm, an alternative to Runge-Kutta based on the mid-point method
  - New G4InterpolationDriver field driver class using Runge-Kutta method with interpolation property to integrate equation of motion with error control
  - **Updated field steppers to make use of cached field values**

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Selected information from non-physics highlights (cont'd)

- Global
  - **Replaced POSIX threading with C++11 threading**, enabling multi-threading on Windows for use with either static or DLL libraries
- Run
  - Added track/step/volume information in G4ExceptionHandler when an exception happens while event is being processed
- Examples
  - Extended example (in extended/field/field01) to demonstrate use of G4PhysicsListHelper's Use[Low|High]LooperThresholds() methods and to demonstrate fine grained control of G4[Coupled]Transportation parameters for (killing) looping tracks
  - New example (in extended/optical) for investigation of optical properties and parameters

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Selected information from non-physics highlights (cont'd)

- Data sets
  - New versions: G4EMLOW7.7, G4SAIDDATA2.0, G4PARTICLEXS1.0, G4RadioactiveDecay5.3, G4PhotonEvaporation5.3, G4INCL1.0
    - Deprecated and no longer necessary G4NEUTRONXS data set
- CLHEP
  - Version 2.4.1.0 (or higher) required

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Selected information from EM physics highlights

- Standard EM models updates
  - Models of single and multiple scattering for e+-
    - **Improved sampling of displacement for the G4UrbanMscModel**
    - Added Mott corrections to G4WentzelVIModel used for simulation of multiple scattering of e+- above 100 MeV
    - G4ScreenedMottCrossSection – use G4MottData shared between threads and implemented more optimal computations
    - G4GoudsmithSoundersonMscModel – fix initialization and added extra access method to transport cross section
  - Gamma models and bremsstrahlung
    - **G4ModifiedTsai – use as a default for bremsstrahlung and pair production, added new method SamplePairDirection, improved performance**
    - G4BetheHeitlerModel, G4PairProductionRelModel – improved screening function approximation, LPM function approximation, selection of elements in compounds
    - G4SeltzerBergerModel – added optional mechanism of sampling final state using sampling table

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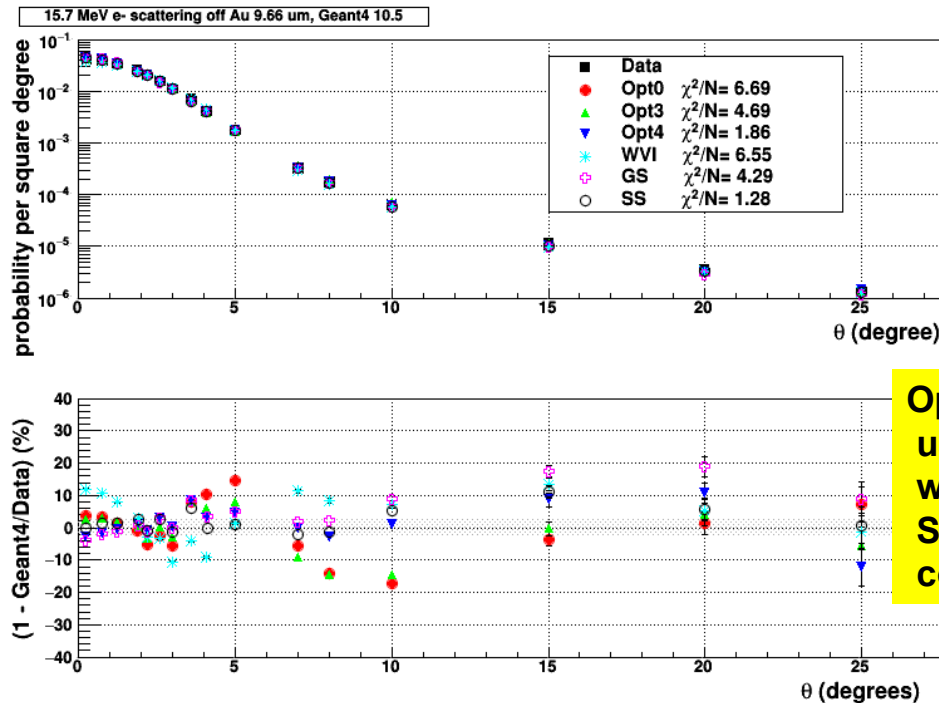# Selected information from EM physics highlights (cont'd)

- New standard EM models
  - G4BetheHeitler5DModel
    - Accurate sampling of final state (~100 slower)
    - Nuclear recoil and polarization are taken into account
  - Proton/hadron ionization
    - Added possibility to use ICRU90 data for stopping powers
      - International Commission on Radiation Units & Measurements (icru.org)
  - Ion ionization based on Lindhard-Sorensen theory
    - G4LindhardSorensenModel – parameterization above 10 MeV
    - G4AtimaEnergyLossModel – implementation of ATIMA code in C++
    - G4AtimaFluctuations – relativistic ion energy loss fluctuations
  - 3-gamma annihilation model
    - G4eplusTo2GammaOKVIModel and G4eplusTo3GammaOKVIModel implements 2- gamma and 3-gamma positron annihilation in flight and at rest
    - Using triplet interface introduced in 10.4
    - Probability of 3-gamma final state depends on cut to gamma energy

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Selected information from EM physics highlights (cont'd)

- EM infrastructure updates
  - G4EmCalculator updated
    - Fixed computation of dE/dx for ions
    - Fixed computation of transport cross section for multiple scattering
  - Fixed problems
    - #1992 (Infinite loop in e+ tracking)
    - #2056 (Incorrect Cerenkov and scintillation GetNumPhotons())
    - #2089 (Incorrect differential cross section of photoelectrons in G4LivermorePolarizedPhotoElectricModel)

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Selected information from EM physics highlights (cont'd)

Hanson data for electron scattering off Gold target *(Phys. Rev.* **84**, 634-637, 1951)

15.7 MeV e- scattering off Au 9.66 um, Geant4 10.5

■	Data	
●	Opt0	$\chi^2/N= 6.69$
▲	Opt3	$\chi^2/N= 4.69$
▼	Opt4	$\chi^2/N= 1.86$
✳	WVI	$\chi^2/N= 6.55$
✚	GS	$\chi^2/N= 4.29$
○	SS	$\chi^2/N= 1.28$

Opt4 Physics List uses the GS model with Mott corrections SS also uses Mott corrections

10   Geant4 10.5 EM physics   18/01/2019

Selected information from EM physics highlights (cont'd)

- EM physics constructors
  - Default EM physics (Opt0)
    - **New lateral displacement for the Urban model**
    - **G4ModifiedTsai for angular distribution of bremsstrahlung and gamma conversion**
  - LHCb type of EM physics (Opt2)
    - Check of options was done and tuned to be the same as in LHCb
  - Accurate EM physics (Opt4)
    - Use GS model of multiple scattering below 100 MeV with "errorless" stepping option
  - Livermore and Penelope physics
    - Use GS multiple scattering as in Opt4 EM physics
  - Experimental EM configurations (WVI and LE)
    - New standard models are included
  - EM physics configuration via UI commands is improved
    - Still work in progress

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Selected information from EM physics highlights (cont'd)

- Summary of EM changes
  - **Due to modifications in Urban MSC model one may expect a shift of calorimetric results of ~1%**
  - EM constructors Opt0, Opt4, Liv, Pen ... provide calorimetric results closer to each other
  - Opt2 (EMX) constructor now is equivalent to the LHCb configuration
  - Several new models are provided
    - They are not included in production physics constructors but in experimental ones only
  - **No significant change in CPU performance due to EM physics is expected for Geant4 10.5**
    - **(e.g. when using FTFP_BERT physics list)**

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Selected information from hadronic physics highlights

- Hadronic Data Sets
  - New
    - G4PARTICLEXS1.1 (mandatory for FTFP_BERT)
      - replaces G4NEUTRONXS2.0 ; pointed by G4PARTICLEXSDATA
    - G4INCL1.0
      - new, needed only by INCLXX ; pointed by G4INCLDATA
  - Updated
    - G4SAIDDATA2.0
    - PhotonEvaporation5.3
    - RadioactiveDecay5.3
  - Unchanged
    - G4ENSDFSTATE2.2, G4NDL4.5, G4ABLA3.1, G4TENDL1.3.2

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Selected information from hadronic physics highlights (cont'd)

- ## String models (1/3)
  - For both FTF (Fritiof) & QGS (Quark Gluon String)
    - **Released the latest versions of the models - developed since 10.2 but not included in 10.3 and 10.4, to keep hadronic showers stable**
    - Development driven to improve the description of thin-target data
    - Observed higher energy response for hadronic showers in calorimeters, (it is not due to π° production)
    - **Reviewed Birks' quenching : noted inconsistent use of Birks' coefficient taken from publications where no-delta-ray emissions were assumed**
  - First implementation of alpha cluster structure of carbon nuclei (affecting only h – C interactions)

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Selected information from hadronic physics highlights (cont'd)

- ## String models (2/3)

  - ### FTF (Fritiof) model

    - **New values of the model parameters, for both string formation and string fragmentation**

    - Introduced smearing of delta-isobar mass and improved di-quark fragmentation into baryons in Lund string fragmentation

    - First implementation of rotating strings, at the level of string fragmentation, with introduction of Mt distribution of hadrons

    - Improved process probability parameterizations for π-nucleon interactions; corrected calculation of nuclear residual excitation energy

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Selected information from hadronic physics highlights (cont'd)

- ## String models (3/3)

  - ### QGS (Quark Gluon String) model

    - **Major revision of the final-state model**
      - implemented Reggeon cascading and "Fermi motion";
      - new algorithm for the determination of the kinematical properties of partons;
      - improved formation of the residual nucleus

  - ### Improved cross-sections of K-meson - nucleon interactions

    - Pomeron and 2 non-vacuum exchanges are taken into account
    - Gamma-nucleon cross sections are improved by parameter tuning
    - Improved string fragmentation : new algorithm for last string decay a-la Lund; refined algorithm to stop the fragmentation
    - Tuning the parameters related to both string formation and string fragmentation to improve the description of thin-target data

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Selected information from hadronic physics highlights (cont'd)

- Intra-nuclear Cascade models
  - Bertini-like (BERT)
    - **Extended strange pair production channels to multibody final states**
      - 6,7,8 and 9 bodies
    - A few important fixes (affecting the physics results)
  - Binary (BIC)
    - Stable, no developments
  - Liege (INCLXX)
    - **Improved strangeness and the few-nucleon-removal**
      - Fixed various bugs
    - New data-set : G4INCL1.0

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Selected information from hadronic physics highlights (cont'd)

- Precompound / de-excitation models
  - **Coherent use of the same parameterization of level density and pairing correction between all models in de-excitation and precompound**
  - Several code improvements
  - New data-set : PhotonEvaporation5.3
- Radioactive Decay model
  - **Improved electron capture**
  - New data-set : RadioactiveDecay5.3
- ParticleHP & LEND (Low Energy Nuclear Data) models
  - Bug fixes, no new development

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Selected information from hadronic physics highlights (cont'd)

- ABLA (EVAPORATION/FISSION MODEL)
  - Extended to hypernuclei
  - Can be used as an alternative de-excitation model for INCLXX
- Elastic scattering
  - Extended the high-energy applicability of G4DiffuseElastic and G4NuclNuclDiffuseElastic up to 100 TeV
- "Extensions"
  - **Made easier to change the high-energy limit of applicability of hadronic physics (which is still 100 TeV by default)**
    - Requested by a cosmic ray experiment (DAMPE)
  - Possible to run Geant4, in the whole energy range of applicability, for transuranic elements
    - Interest from an ADS (Accelerator Driven System) project (MYRRHA)

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Selected information from hadronic physics highlights (cont'd)

- Cross Sections
  - Replaced environment variable G4NEUTRONXSDATA with G4PARTICLEXSDATA
  - Several technical improvements
  - New class G4NeutrinoElectronTotXsc for total cross-section of neutrino – electron interactions
    - Neutral + charged currents
  - **Improved Barashenkov-Glauber-Gribov (BGG) elastic, inelastic and total cross sections**
    - For pions, kaons and protons
    - In particular for Hydrogen target
    - Extended for hyperon projectiles

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Selected information from hadronic physics highlights (cont'd)

- Physics Lists
  - For pions, FTF / QGS / INCLXX **physics-lists builders use Barashenkov-Glauber-Gribov inelastic cross-section**
    - **Avoiding to use Gheisha cross sections for inelastic π± H**
  - Both QGSP_BIC_HP and QGSP_BIC_AllHP use EM Opt4
    - Instead of EM Opt0 as before

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Selected information from hadronic physics highlights (cont'd)

- Hadronic showers

  - **Hadronic showers in Geant4 10.5 change significantly**

    - Few per-cent higher energy response

    - Smaller fluctuations of energy response

    - Wider lateral shapes

    mostly due to the development in string models (improved description of thin-target data)

    - **First two aspects (energy response – mean and fluctuations) are affected by the Birks' quenching: a new treatment is recommended:**

      - **Fit the Birks' coefficient based on h/e test-beam data**

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A slide from Chris Pinkenburg's talk on sPHENIX at Geant4 Technical Forum on 9/24/2019

Physics Lists (Geant4 10.02.p02)

W-Epoxy/Scintillating Fiber EMCal
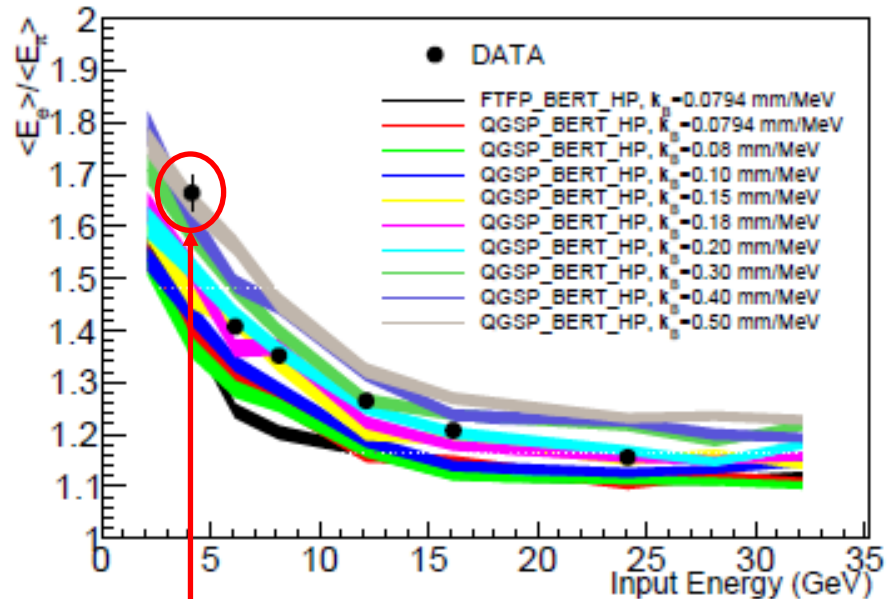
https://arxiv.org/pdf/1704.01461v1.pdf

Inner + Outer HCal

π @ 4 GeV contaminated by μ
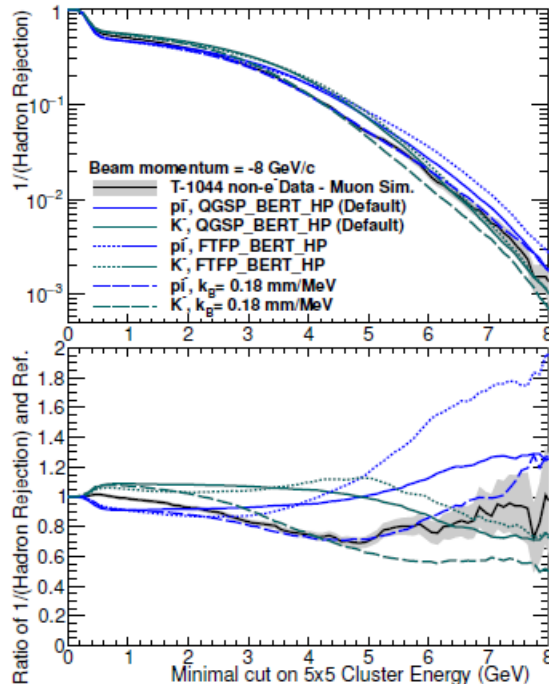
Hadron (mostly π^-, < 1%K^-) rejection as function on energy cut in 5x5 towers. Sensitive to lateral shower sizes

Minor effect of physics list but big influence of Birks constant: Data best described by 0.2mm/MeV Birks constant

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Geant4 patch 10.5.p01

- Some aspects mentioned at the technical forum:
  - https://indico.cern.ch/event/825319/timetable/#20190924.detailed
- Release notes
  - https://cern.ch/geant4-data/ReleaseNotes/Patch4.10.5-1.txt
- Selected Bugzilla problem reports addressed – 1

  #1824 – G4ParticleHPPhotonDist::GetPhotons() needs statistical rejection if repFlag is 0

  #2085 – Optical messenger commands not working

  #2089 – Differential cross-section of photo-electrons in G4LivermorePolarizedPhotoElectricModel

  #2111 – G4Polycone fails to find intersection between line and cone

  #2123 – Excited nucleus sometimes fails to decay

  #2126 – G4mplonisationWithDeltaModel produces too many delta electrons

  #2133 – Pressure/temperature not changing in ConstructNewIdealGasMaterial

  #2134 – Wrong density calculation in ConstructNewIdealGasMaterial

  #2138 – G4FTFPModel has a memory leak

  #2140 – Release of static G4AssemblyStore results in segmentation fault

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Geant4 patch 10.5.p01 (cont'd)

- Selected Bugzilla problem reports addressed – 2

  #2142 – Physical volume with more than 2 BorderSurface not written correctly in GDML

  #2143 – Different OpIcalSurface with same MaterialProperIesTable not written correctly in GDML

  #2145 – G4LogicalVolume null FieldManager propagation

  #2147 – FPE exception trapping doesn't work on MacOS

  #2150 – Set cut in range for protons to zero for HP physics

  #2152 – The energy of GenericIon increases infinitely

  #2156 – GDML export seg-faults in MT mode

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Geant4 10.6; released December 6th, 2019; patch released on February 14th, 2020

- Technical forum: https://indico.cern.ch/event/780834/timetable/#20200116.detailed

16:00			
	Introduction		*Makoto Asai*
	13/2-005, CERN		16:00 - 16:08
	What's new in 10.6 - non-physics part		*Dr Gabriele Cosmo*
	13/2-005, CERN		16:08 - 16:21
	What's new in 10.6 - EM physics part		*Prof. Vladimir Ivantchenko*
	13/2-005, CERN		16:21 - 16:34
	What's new in 10.6 - Hadronic physics part		*Alberto Ribon*
	13/2-005, CERN		16:34 - 16:47
	Open requirements		*Marc Verderi*
	13/2-005, CERN		16:47 - 17:00
17:00	**ATLAS**		*Marilena Bandieramonte*
	13/2-005, CERN		17:00 - 17:12
	CMS		*Sunanda Banerjee et al.*
	13/2-005, CERN		17:12 - 17:24
	Geant4 in LArTPC simulation		*Tingjun Yang*
	13/2-005, CERN		17:24 - 17:36
	"pyg4ometry" to load/manipulate/save/visualise/convert GDML/Fluka/CAD geometry	*Prof. Stewart Takashi Boogert et al.*	
	13/2-005, CERN		17:36 - 17:48
	Tetrahedral mesh navigator		*Haegin Han*
	13/2-005, CERN		17:48 - 18:00
18:00			

- Release notes:
  - http://geant4.web.cern.ch/geant4/support/ReleaseNotes4.10.6.html
  - http://geant4-data.web.cern.ch/geant4-data/ReleaseNotes/Patch4.10.6-1.txt

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Selected information from non-physics highlights

- Geometry - Geometrical primitives
  - Updated **VecGeom** library, VecGeom v1.1.5
    - Selection which shapes to enable made during the (build) configuration stage
    - Introduced generation of polyhedral meshes for all shapes
    - First implementation of dedicated GDML reader for persistency
    - Added more shapes (ellipsoid, elliptical-tube, elliptical-cone)
      - **All shapes (except for the twisted ones) are now available**
  - **Revised algorithms for overlaps checking**
    - Speedup and improved diagnostics **(~50x speedup in Mu2e case)**
  - G4ExtrudedSolid: **fixed a bug affecting extruded solids defined off-center along the z-axis**

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Selected information from non-physics highlights (cont'd)

- Geometry - Navigation, Field
  - Added hooks for enabling partial or complete replacement of navigation algorithms in Geant4
    - Allowing interfacing with Flair/Moira for use of FLUKA geometries with Geant4
    - First prototype implementation of a navigator based on VecGeom
  - **Reviewed treatment of looping particles in field propagation**
    - **Enhanced diagnostics and settings, fully under user control**
  - Enabled default use of interpolation for intersection calculation in field propagation
    - Selection between the new interpolation-capable integration scheme, for shorter steps, and a helix-based scheme chosen for steps larger than 2*pi times the curvature radius at the initial location
  - C++11 revision of geometry code

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Selected information from non-physics highlights (cont'd)

- Global

  – Reviewed and optimized G4PhysicsVector (added additional Value() method option to propagate down the known log-energy value), avoiding log() calls when log-vector is used and providing CPU run-time boost

  – Added functionality in G4DynamicParticle to provide log-kinetic energy value, computed only on demand; reviewed EM processes to select the target atom by making use of the already known log-energy value in the log-vector access providing additional measurable CPU speedup

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Selected information from non-physics highlights (cont'd)

- Configuration & Externals
  - CMake
    - CMake v3.8 or higher now required and enforced
  - Pre-processor flags are promoted to fixed #define statements in a generated header. User code relying on these macros should include the G4Types.hh header to make them available
  - **Preprocessor macros G4UI_USE and G4VIS_USE are removed**
- CLHEP
  - Version 2.4.1.3 required (2.4.1.2 should work as well in most of the cases)

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Selected information from EM physics highlights

- Materials
  - New static methods added
    - G4Material::GetMaterial(const G4String&, G4double density)
    - G4Material::GetMaterial(G4double Z, G4double A, G4double density)
    - G4Material::GetMaterial(size_t nComponents, G4double density)
      - These methods may help to reduce duplicate material definitions in detector descriptions
  - New class G4DensityEffectCalculator (Matthew Strait, University of Minnesota, NOvA)
    - Based on R.M.Sternheimer publications as the default but does not use parameterization, solving a non-linear equation instead
    - **Per a user request compute density effect correction on fly without any parameterization (~1% level dE/dx effect)**
      - **New UI command "/material/g4/enableDensityEffOnFly material name"**
    - **The correction is turned off by default in the production code**
  - Default computation of the density correction for compounds changed
    - If a compound is not inside NIST materials DB but some element dominates in the mass fraction (>90 %), then density correction is based on parameterization for this pure element available in Geant4

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Selected information from EM physics highlights (cont'd)

- Model developments
  - **Focused on CPU performance improvements**
  - Number of problem report and requests were addressed for **improvements in configuration of EM models and EM parameters**
    - General process approach for gamma is available
    - New helper class G4NIELCalculator
    - Gamma conversion to muon pair process is extended down to production threshold (request from Gamma Factory R&D group)

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Selected information from EM physics highlights (cont'd)

- EM code was reviewed, and **several optimizations were introduced**
  - At any step of each track EM energy loss, ranges, cross sections were recomputed using internal tables
  - Energy scales of tables are logarithmic over particle kinetic energy
    - Main **optimization** was to **compute the logarithm only once if the energy is the same**
    - This also allowed to substantial simplify interpolation code reducing number of lines of code used at a step practically by a factor of 10
  - **A total effect of a few (~5)% of CPU in a CMS case**

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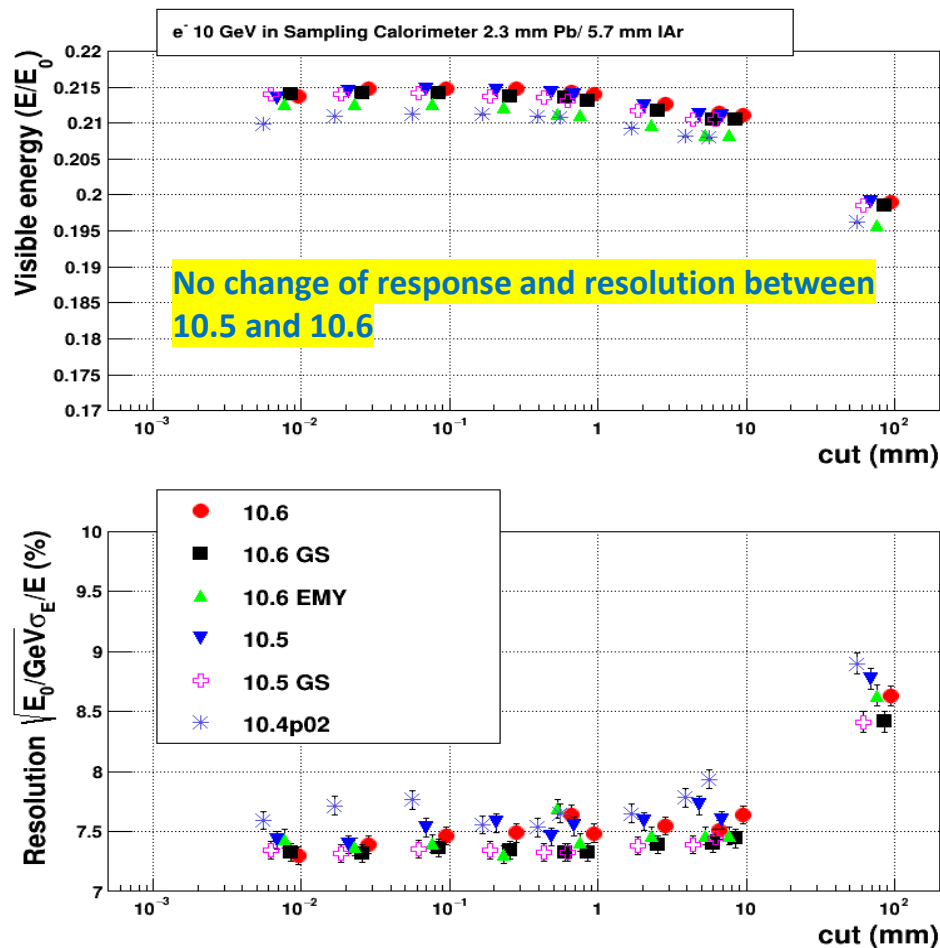
Selected information from EM physics highlights (cont'd)

- # General Gamma Process
  - **Optional replacement of**
    - **Photo effect, Rayleigh, Compton, e+ e- pair production , Gamma- nuclear, Mu+ Mu- pair production processes by one G4GammaGeneralProcess**
  - Stepping Manager sees only one physics process
  - Enabled via UI command
  - Is the default for Opt1 (EMV) EM physics
  - Reduced number of instructions
    - ~5% CPU effect, some small memory cost
  - CPU/memory effect application dependent

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Selected information from EM physics highlights (cont'd)

- Configuration of EM physics
  - A set of EM physics constructors is provided together with each recent Geant4 version
    - The default (Opt0) EM physics is optimized for use in HEP
    - The Opt1 (EMV) and Opt2 (EMX) variants use simplified multiple scattering and other options
    - The alternative Opt4 (EMZ) physics is a combination of the most accurate EM models
      - Is recommended for R&D and detector performance studies
      - In 10.6 will also use 5D (5differential) gamma conversion model
      - Substantially slower than Opt0
  - **Additional EM physics configuration possible via UI commands and C++ interface (G4EmParameters class)**

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Selected information from EM physics highlights (cont'd)

Cut dependence of ATLAS type simplified calorimeter response

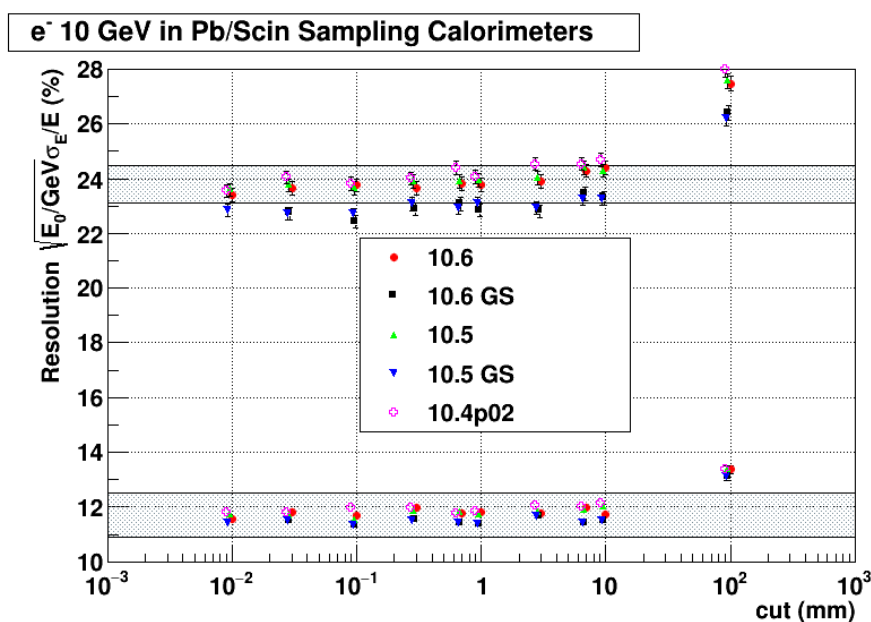e⁻ 10 GeV in Sampling Calorimeter 2.3 mm Pb/ 5.7 mm lAr

No change of response and resolution between 10.5 and 10.6

Legend:
- 10.6
- 10.6 GS
- 10.6 EMY
- 10.5
- 10.5 GS
- 10.4p02

Resolution of Pb/Sc calorimeters

Bernardi E. et al. 1987 Nucl. Instrum. Meth. A **262**, 229

- Resolution for 10.5 and 10.6 is lower but within data errors
  - Effect is visible for high sampling fraction (thicker scintillator)

Selected information from hadronic physics highlights

- Hadronic Data Sets
  - Updated
    - G4PARTICLEXS2.1
    - PhotonEvaporation5.5
    - RadioactiveDecay5.4
    - G4NDL4.6
  - Unchanged
    - G4ENSDFSTATE2.2
    - G4SAIDDATA2.0
    - G4INCL1.0
    - G4ABLA3.1
    - G4TENDL1.3.2

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Selected information from hadronic physics highlights (cont'd)

- Hadronic String models
  - For both FTF (Fritiof) & QGS (Quark Gluon String)
    - Extended both Lund and QGS string fragmentation to allow the possibility to have charmed and/or bottom quarks and diquarks in the strings. As a result of the hadronization of strings having heavy (c, b) quarks, charmed and bottom hadrons can be produced: only heavy mesons and baryons that can fly macroscopic distances are considered as candidate final states.
      - **But for this release G4 10.6, inelastic processes for heavy hadrons are not included in any physics lists**
  - Included the possibility to produce charmed and bottom hadrons from the string fragmentation of ordinary strings
    - **But for the release G4 10.6, these probabilities are set to 0**

Selected information from hadronic physics highlights (cont'd)

- Intra-nuclear Cascade models
  - Bertini-like (BERT)
    - **Improved gamma–deuteron interactions**
    - A few fixes
  - Binary (BIC)
    - Stable, no developments
  - Liege (INCLXX)
    - No changes

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Selected information from hadronic physics highlights (cont'd)

- Precompound / de-excitation models
  - Several code improvements
  - New data-set : PhotonEvaporation5.5

- **Radioactive Decay model**
  - **Added: spontaneous fission channel, and radioactive decay mode with emission of triton**
  - Various technical improvements and bug fixes
  - New data-set : RadioactiveDecay5.4

Selected information from hadronic physics highlights (cont'd)

- **ParticleHP & LEND (Low Energy Nuclear Data) models**
  - Stable, no developments; Several bug fixes in ParticleHP
  - **New data-set : G4NDL4.6 (based on different evaluated cross-sections)**
    - https://geant4.web.cern.ch/support/data_files_citations
    - G4NDL (Geant4 Neutron Data Library, with or without thermal neutrons**)**
      - Neutron cross-sections and final states are obtained from JEFF-3.3 (Joint Evaluated Fission and Fusion File) https://www.oecd-nea.org/dbdata/jeff/jeff33/index.html (previously, before Geant4 release 10.6, they were based mainly on ENDF/B-VII.1). Files not coming from JEFF-3.3 and corresponding to previous G4NDL versions are: JENDL_HE, IsotopeProduction, ThermalScattering, Inelastic/Gammas, Fission/FF. Information concerning the conversion process of JEFF to the G4NDL format can be found in:
        - E. Mendoza and D. Cano-Ott, IAEA technical report INDC(NDS)-0758, Vienna, 2018.
        - The *ENDF/B-VII* library is developed and maintained by the Cross-Section Evaluation Working Group (CSEWG)
    - **Switching to this more complete dataset changes/increases n, e and gamma production**
    - The authors (EMC) suggest defining the G4NEUTRONHP_DO_NOT_ADJUST_FINAL_STATE and G4PHP_DO_NOT_ADJUST_FINAL_STATE flags, which disables the energy/momentum conservation in reactions when the dataset is used, which improves the agreement with MCNP6
    - Defining G4NEUTRONHP_USE_ONLY_PHOTONEVAPORATION causes the EM cascades after neutron capture being produced by the photon evaporation model where the energy is conserved
      - Currently, by default, if ParticleHP does not find data for a given isotope, it tries to use the data for a "similar" one, which may not be the right thing to do. As an alternative one may define G4NEUTRONHP_SKIP_MISSING_ISOTOPES, as those are usually a very rare ones
    - For the few isotopes not present in the new dataset, possibly copy them from the old dataset if present
    - Also see https://indico.cern.ch/event/886823/contributions/3754986/attachments/1990745/3318882/G4NDL46_G4HMFeb2020_v01.pdf

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Selected information from hadronic physics highlights (cont'd)

- Elastic scattering

  - **Extended pion-elastic scattering to lower energies**
    - G4ElasticHadrNucleusHE: before it was used only above 1 GeV (while below Gheisha was used). It is used for all energies now

  - **Use Glauber-Gribov cross-sections for hyperons and anti-hyperons elastic nuclear interactions**
    - **In all physics lists** (instead of using Gheisha XS)

  Note a mistake in the Release Notes:

  - "Removed tracking cut in hadron elastic..." but there is no tracking cut in hadron elastic ! **If hadron energy was below 1 keV, there was no scattering (i.e. hadron kept going forward, unchanged) in G4 10.5 (and earlier). Now this threshold is much smaller: 10^-6 eV**

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Selected information from hadronic physics highlights (cont'd)

- **Cross Sections**
  - **Reviewed and improved the low-energy behavior of all hadron – nucleon (elastic and inelastic) cross sections**
    - Used by Glauber-Gribov hadron – nucleus cross sections
  - **Use Glauber-Gribov cross-sections for hyperons and anti-hyperons nuclear interactions**
    - **Both elastic and inelastic**
  - Extended Glauber-Gribov cross sections for charmed and bottom hadrons (mesons and baryons)
    - Not used in physics lists yet
  - Removed Gheisha cross sections (used as a default in the past)
    - There are better alternatives for all cases
  - In the patch in G4HadronInelasticDataSet fixed wrong GHEISHA x-section, addressing problem report #2220
  - In the patch in G4BetaPlusDecay changed sign of daughterZ argument in G4BetaDecayCorrections according to problem report #2199

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Selected information from hadronic physics highlights (cont'd)

- Physics Lists (1/2)

  - **Changed transition region between hadronic string models and intra-nuclear cascade models**

    - **Now it is [3, 6] GeV consistently for all particle types**

      - nucleons, pions, kaons : before it was [3, 12] GeV hyperons : before it was [2, 6] GeV

      - ions : before it was [2, 4] GeV/nucleon

      - gammas : before it was [3, 3.5] GeV

      - anti-baryons : no changes here, FTFP is still used for all energies

  - Note: this does not affect the physics lists FTFP_BERT_ATL , FTFP_INCLXX , QGSP_INCLXX , NuBeam , ShieldingM

  - Note: for the QGS-based physics lists, the transition between FTFP and QGSP remains unchanged, [12, 25] GeV

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Selected information from hadronic physics highlights (cont'd)

- Physics Lists (2/2)
  - **Added RadioactiveDecay to all HP-based physics lists**
    - This affects the physics lists: FTFP_BERT_HP, QGSP_BERT_HP, FTFP_INCLXX_HP and QGSP_INCLXX_HP
      - **Shielding(M) , LBE , QGSP_BIC_HP and QGSP_BIC_AllHP were using it already**

- New stopping physics constructor based on FTF + BIC for the anti-baryon annihilation at rest
  - G4StoppingPhysicsFritiofWithBinaryCascade

  used only in the physics lists FTF_BIC and QGS_BIC

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Selected information from hadronic physics highlights (cont'd)

- Hadronic showers

  - **Hadronic showers in 10.6 change mainly for projectile energies between 5 – 20 GeV**

    - **Higher energy response**

    - **Narrower showers**

    mostly due to change of the energy transition region

    - Not for: FTFP_BERT_ATL , FTFP_INCLXX , QGSP_INCLXX , ShieldingM , NuBeam

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Geant4 patch 10.6.p01

- Technical forum: https://indico.cern.ch/event/895400/timetable/#20200323.detailed

16:00		
Introduction		*Makoto Asai*
Vidyo, CERN		16:00 - 16:04
Patch release 10.6-p01 and 2020 work plan - non-physics part		*Dr Gabriele Cosmo*
Vidyo, CERN		16:04 - 16:18
Patch release 10.6-p01 and 2020 work plan - EM physics part		*Vladimir Ivantchenko*
Vidyo, CERN		16:18 - 16:32
Patch release 10.6-p01 and 2020 work plan - Hadronic physics part		*Alberto Ribon*
Vidyo, CERN		16:32 - 16:46
Open requirements		*Marc Verderi*
Vidyo, CERN		16:46 - 17:00

17:00		
ATLAS		*Miha Muskinja*
Vidyo, CERN		17:00 - 17:15
CMS		*Sunanda Banerjee et al.*
Vidyo, CERN		17:15 - 17:30
Constraining the anti-deuteron nuclear inelastic cross-section with ALICE		*Ivan Vorobyev*
Vidyo, CERN		17:30 - 17:45

- https://cern.ch/geant4-data/ReleaseNotes/Patch4.10.6-1.txt

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Selected information from non-physics highlights

- Geometry
  - Geometrical primitives & navigation/field
    - Avoid potential cases of looping in G4RegularNavigation by enabling pushing mechanism with increasing step size. Problem report #2196
    - Re-established parameterization mechanism for G4Tet and G4UTet which was removed by mistake. Problem report #2209
    - Revision of G4Tet, fixing issues detected in unit tests and speedup
      - Implemented SetVertices(), direct modifier for vertices
    - Revision of G4Ellipsoid, fixing issues of stuck tracks (30-70% speed-up) Problem report #2206
    - Added protection in G4VFacet header for double definition of global symbols from Windows Kits code
    - **Switched off verbosity by default in field driver classes**

Selected information from EM physics highlights

- In muon e+e- pair production added an option to allow to retrieve precomputed PDF from the data files
  - /process/em/MuDataFromFile true
  - And an equivalent C++ interface
  - Should significantly reduce initialization before the run
- G4BetheHeitler5DModel–fixed a rare numerical problem
- New data set G4EMLOW7.9.1

Selected information from hadronic physics highlights

- Cross sections
  - G4HadronInelasticDataSet : fixed wrong Gheisha cross section. Addressing problem report #2220
    - Does not affect the main reference physics lists
- Management
  - G4HadronicProcess : for charge check, assume that all final electrons come from internal conversion
- Processes
  - G4HadronElasticProcess : removed forgotten try/catch pattern for target isotope selection

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Selected information from hadronic physics highlights (cont'd)

- BERT

  – G4CascadeCheckBalance : **fixed outstanding problem of the interface with native pre-compound model, happening when in the default de-excitation, internal electron conversion gets enabled**

  – G4CascadeInterface : fixed memory leak by correcting the destructor

  – G4CascadeParamMessenger : ensure that Bertini-specific commands get added to "/process/had/cascade/" UI directory, instead of "/process/had/"

- FTF

  – G4FTFParameters : fixed division by zero (Coverity report) due to wrong protection

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Selected information from hadronic physics highlights (cont'd)

- Coherent Elastic Model
  - G4ElasticHadrNucleusHE : for pi- and Z>1 reuse data structure computed for pi+ in order to reduce memory and CPU at initialization; added new private methods to store/retrieve data tables.
  - Co-works with new data-set G4EMLOW-7.9.1 . Fixed Coverity report.
  - Switch to parameterized model based on kinetic energy and not momentum

- Radioactive Decay
  - G4Radioactivation::AddDeexcitationSpectrumForBiasMode() : fixed memory leak. Addressing problem report #2164
  - G4RadioactiveDecay, G4RadioactiveDecayBase : changed default verbosity from 0 to 1, and removed G4cerr wherever it occurred and replaced it with G4Exception or G4cout.
  - **Increased verbosity thresholds in order to reduce printout size**

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Selected information from hadronic physics highlights (cont'd)

- Radioactive Decay (cont'd)
  - G4BetaPlusDecay : changed sign of daughterZ argument in G4BetaDecayCorrections according to problem report #2199
  - Fixed Coverity warnings in G4RadioactiveDecay and G4RadioactiveDecayBase
  - Fixed uninitialized data in G4SFDecay
- Physics lists
  - LBE : updated cross-sections to avoid crashes caused by the removal of default Gheisha cross-sections, and to have consistency between elastic and inelastic cross-sections

CPU comparisons (measurements done by Julia Yarba) http://g4cpt.fnal.gov

- https://g4cpt.fnal.gov/g4p/oss_10.5.p01_SimplifiedCalo_01/cpu_summary.html

Sample	Physics List	B-Field	Energy	CPU/event
	FTFP_BERT	4.0T	100 MeV	18.0480
100 MeV e- (5K e-/event)	Shielding	4.0T	100 MeV	38.5160
	Shielding_EMZ	4.0T	100 MeV	108.1900

- https://g4cpt.fnal.gov/g4p/oss_10.5.p01static_SimplifiedCalo_01/cpu_summary.html

Sample	Physics List	B-Field	Energy	CPU/event
	FTFP_BERT	4.0T	100 MeV	15.8280
100 MeV e- (5K e-/event)	Shielding	4.0T	100 MeV	32.8940
	Shielding_EMZ	4.0T	100 MeV	93.1100

By using static builds one can save >10% of the CPU time

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CPU comparisons (measurements done by Julia Yarba) http://g4cpt.fnal.gov (using static libraries)

https://g4cpt.fnal.gov/g4p/summary/cpu_SimplifiedCalo_proton.html
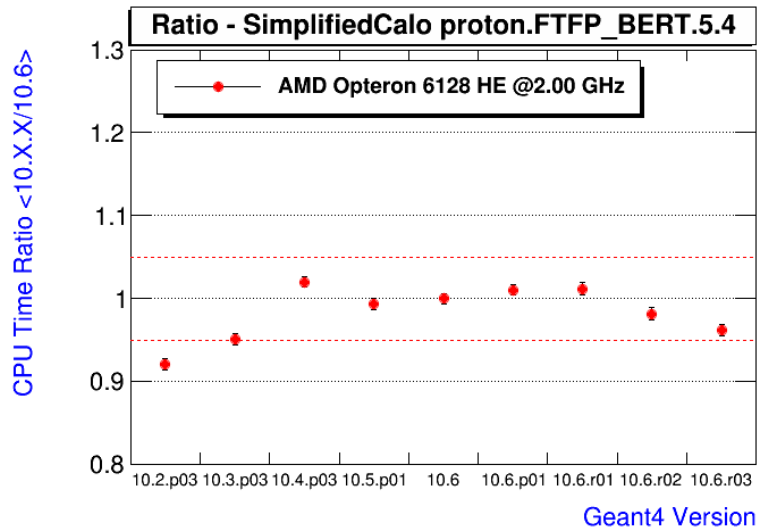
CPU time ratios;
10.6 set to 1
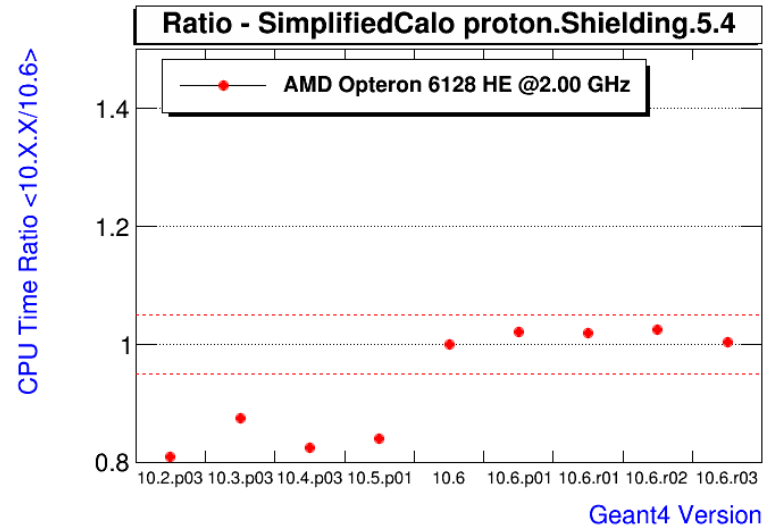
New G4NDL4.6 dataset in 10.6
for ParticleHP

5GeV protons;
4T field
Cu/Scintillator
sandwiched
calorimeter

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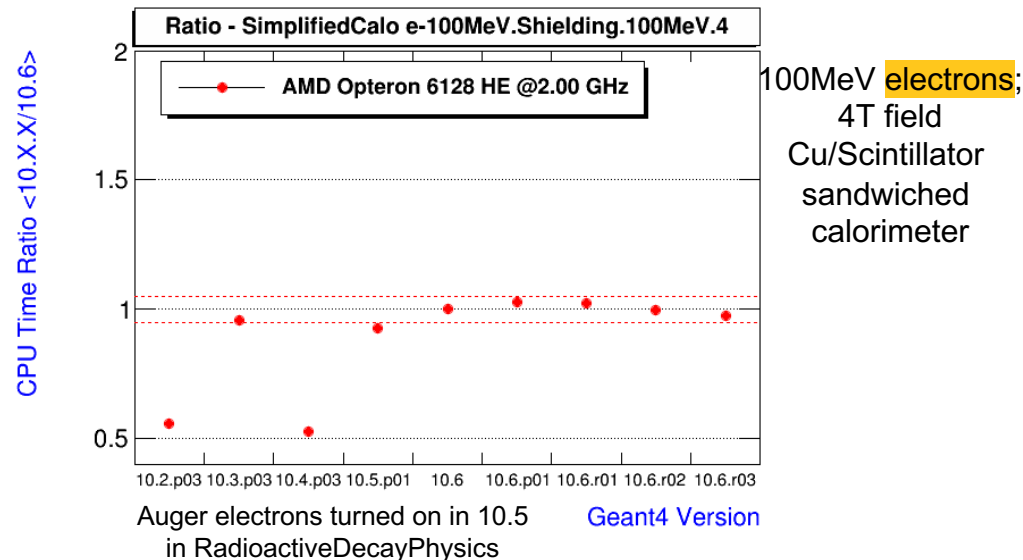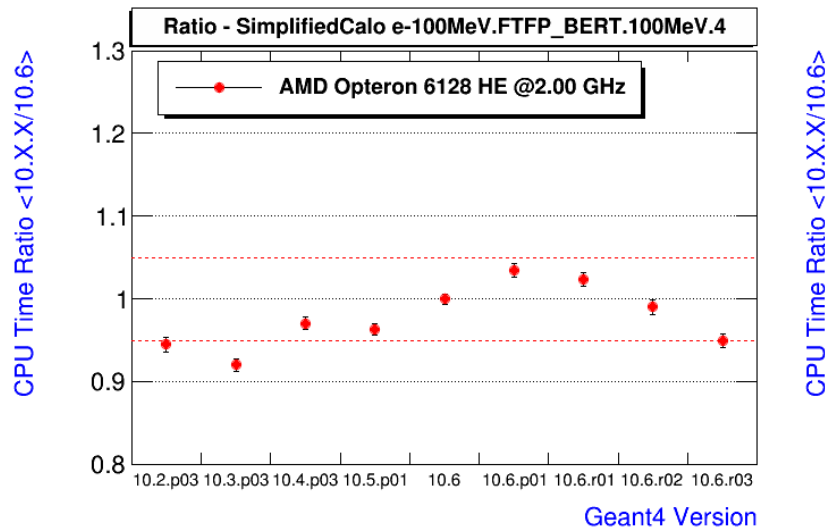# CPU comparisons (measurements done by Julia Yarba) http://g4cpt.fnal.gov (using static libraries)

- https://g4cpt.fnal.gov/g4p/oss_10.6.p01_SimplifiedCalo_01/cpu_summary.html
  – In 10.6 _EMZ list requires much more CPU time in a calorimetric application

Sample	Physics List	B-Field	Energy	CPU/event
100 MeV e- (5K e-/event)	FTFP_BERT	4.0T	100 MeV	17 s
	Shielding; uses HP&RD	4.0T	100 MeV	36 s
	Shielding_EMZ	4.0T	100 MeV	107 s

https://g4cpt.fnal.gov/g4p/summary/cpu_SimplifiedCalo_electron.html

CPU time ratios;
10.6 set to 1

100MeV electrons;
4T field
Cu/Scintillator
sandwiched
calorimeter

Auger electrons turned on in 10.5
in RadioactiveDecayPhysics

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Summary/Suggestions

- Many changes in each of the Geant4 versions, including EM, hadronic and neutron physics models as well as updates to the cross-sections
- 10.6 represents continuation of changes started in 10.5 with many, may be smaller, but important corrections and fixes
  - Consider using 10.6.p01, after proper physics validation, if possible
    - Report problems found, if any; Another patch to 10.6 is not excluded if needed
    - The 10.4.p03 patch to 10.4 after 10.5 was released was an exception
      - as 10.5 was quite different from 10.4 (esp. the FTF model)
- 10.6 offers more configuration parameters, e.g. in EM models (e.g. MSC model transition energy) or in hadronic models (FTF)
- Consider corrections to the Birks' constants for the materials used, using available experimental data
  - Geant4 10.6.p01 sets the Birks' constant for the following materials: G4_POLYSTYRENE, G4_BGO, G4_lAr, G4_PbWO4
  - Consider a dedicated measurement if needed
- Consider using static builds in production runs
- Consider working with our (PDS) Group on creation of an "official" neutrino experiments dedicated Physics List(s); It could be included in Geant4 December release
  - E.g. ShieldingM is mainly dedicated to Mu2e; There is also NuBeam which may be updated as needed

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Backup Slides

K.L. Genser: Geant4 10.4,10.5,10.6   LArSoft Coordination Meeting   April 7, 2020

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Comments on Birks' quenching

- In the past few years, for the main hadronic string model Fritiof (FTF), unable to improve the description of thin-target and thick-target (hadronic showers) data simultaneously

  – Development driven to improve the thin-target data description gave worse hadronic showers – i.e. higher energy response

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Comments on Birks' quenching (cont'd)

- Was it due to the treatment of the Birks quenching?

- Birks' Quenching:
  - Detector-specific suppression of the "visible" energy with respect to the local "deposited" energy by ionizing particles due to intrinsic saturation effects in light-emitting scintillators or electron-ion recombination effects
  - The higher the local deposited ionization density, dE/dx, the more quenching
  - Described by the simple, phenomenological relation:

    $$\Delta E_{visible} = \Delta E / (1 + K*(\Delta E / \Delta x))$$

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Comments on Birks quenching (cont'd)

- For scintillator-based calorimeters, the coefficient used for Birks' quenching was obtained from old measurements, by fitting under the assumption of **no delta-ray emissions**

  - i.e. assuming that the "energy loss" is the same as the "local deposited energy"

  - This implies that the ionization density, dE/dx, was overestimated, and therefore the **Birks coefficient was underestimated**

  - So, **in realistic simulations** where delta-rays are emitted, **a higher Birks coefficient** – and therefore a bigger quenching – **should be used**, which implies smaller visible energy

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Comments on Birks' quenching (cont'd)

- **The suggestion is to fit the Birks' coefficient by imposing the π / e ratio in simulation to be the same as measured in test-beam data at one (arbitrarily chosen) beam energy**

- The same procedure could be applied for different active media, e.g. liquid Argon and others

- Note: this extra free parameter will, of course, compensate also for some of the uncertainties in modelling hadronic physics, but for different observables (energy fluctuations and shower shapes) at the same energy, as well as for all observables at different energies, there is no reduction in "predictive power"

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CPU comparisons using new and old G4NDL dataset

Example: PbWO$_4$

	14.1 MeV 10 g/cm^3	14.1 MeV 1 g/cm^3	14.1 MeV 0.1 g/cm^3	1 keV 10 g/cm^3
PbWO$_4$	1.42	1.13	1.09	1.59
O	0.98	1.04	1.00	0.98
W	1.30	1.31	1.20	3.33
Pb	0.94	1.04	1.09	1.03
8016	1.00	1.03	0.97	0.98
8017	1.97	3.02	2.37	1.65
8018	-	-	-	-
74180	-	-	-	-
74182	1.31	1.22	1.11	2.30
74183	1.22	1.33	1.28	4.77
74184	1.20	1.37	1.26	1.47
74186	1.83	1.39	1.27	2.06
82204	0.98	0.84	0.82	1.18
82206	1.35	1.03	1.12	1.06
82207	1.10	1.13	1.29	1.28
82208	0.73	0.98	1.00	0.93

W is one of the elements for which CPU increases the most

Table 1: CPU time (G4NDL4.6) / CPU time (G4NDL4.5)

GOBIERNO DE ESPAÑA — MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Ciemat — Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Emilio Mendoza Cembranos
Geant4 hadronic meeting - February 2020

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Geant4 physics list (EM) suffixes and the corresponding physics constructors (in 10.6)

No suffix - G4EmStandardPhysics

_EMV - G4EmStandardPhysics_option1

_EMX - G4EmStandardPhysics_option2

_EMY - G4EmStandardPhysics_option3

_EMZ - G4EmStandardPhysics_option4

_LIV - G4EmLivermorePhysics

_PEN - G4EmPenelopePhysics

__GS - G4EmStandardPhysicsGS

__SS - G4EmStandardPhysicsSS

_EM0 - G4EmStandardPhysics

_WVI - G4EmStandardPhysicsWVI

__LE - G4EmLowEPPhysics

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